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Epidemiology of tungiasis in sub-saharan Africa: a systematic review and meta-analysis

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ABSTRACT

Tungiasis is a public health disease in many rural and urban slums in sub-Saharan Africa (SSA), primarily affecting children and the elderly. Yet, this disease has received little attention in many sub-Saharan African countries. We conducted a systematic review and meta-analysis to estimate the pooled prevalence of tungiasis and associated risk factors in SSA. We searched AJOL, Google Scholar, Web of Science, and PubMed for population-based studies that reported the prevalence of tungiasis and risk factors in SSA between January 1980 and July 2020. The study employed a random-effects model and heterogeneity to estimate the pooled prevalence and evaluate the Cochran's Q-test respectively across studies that met the inclusion criteria. We screened 104 articles and retrieved 42 full-text articles to evaluate for inclusion in the review. Twenty-seven studies involving 16,303 individuals in seven SSA countries were analyzed. The pooled prevalence of tungiasis in SSA was 33.4% (95% CI: 27.6–39.8), while tungiasis prevalence was 46.5%, 44.9%, 42.0%, 37.2%, 28.1%, 22.7% and 20.1% for Ethiopia, Cameroon, Tanzania, Kenya, Nigeria, Rwanda, and Uganda, respectively. The risk of tungiasis was associated with gender, participants' age groups (4–15 years and ≥60 years), earthen floor, non-regular use of footwear, contact with animals, and residence in rural areas. An integrated approach addressing significant factors in tungiasis prevalence in SSA needs to be designed and implemented by a trans-disciplinary composition of community leaders, health professionals, non-governmental institutions, and policymakers.

KEYWORDS
Human; meta-analysis; pooled prevalence; tungiasis; sub-saharan Africa

1. Introduction

Tungiasis is a public health skin disease prevalent in many rural and urban slums and caused by the female sand fleas, *Tunga penetrans* [1,2]. Tungiasis is a zoonosis and affects humans and animals alike in disadvantaged communities in the Caribbean, sub-Saharan Africa (SSA), and South America, primarily affecting children and the elderly [3–5]. *Tunga penetrans*, the causative organism of tungiasis attack mostly the periungual region of children and the elderly, although, infection of the elbows, hands, and genital areas have been reported [6]. Mud or earthen housing materials, poor hygiene behavior, rearing of domestic animals (such as pigs, dogs, and cats) and walking barefoot, have been associated with jigger infection [7,8]. The acute stage of tungiasis is characterized by itching, swelling, deep fissures, ulcers, and abscess development as a result of bacterial superinfection, while the chronic form may be accompanied by protracted pain, deformity, damage to the feet and disability [6,9,10]. Despite the considerable magnitude of the disease, it is widely overlooked by the academic community, health care practitioners, public health experts, decision-makers, funding organizations, and pharmaceutical companies. A prevalence of 80% and up to 60% in children and the general population, respectively has been reported around the world [11]. A point prevalence of between 16–54% has also been reported in low socio-economic prone communities in Latin America, the Caribbean, and sub-saharan African countries [1,5]. The prevalence of tungiasis in the human population has been studied sporadically in SSA [12–18]. However, to the best of our knowledge, no comprehensive study has been conducted on tungiasis in SSA; hence we present the outcome of a systematic review and meta-analysis of the epidemiology of tungiasis in SSA.

2. Materials and methods

We conducted this review in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which provide evidence-based recommendations for conducting and reporting systematic reviews and meta-analyses [19]

2.1. Strategy for bibliography search

An in-depth literature search was performed on articles published on Google Scholar, PubMed, African Journals OnLine (AJOL), and Web of Science without

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language restriction from January 1980 to June 2020. This study included all studies, and cross-references of those that reported the prevalence or epidemiology of tungiasis in humans.

Our search strategy applied the following keywords: 'prevalence', 'epidemiology', '*Tunga penetrans*', 'tungiasis', 'chigoe', 'jigger', '*Puce-chique*' and 'human'. Regional specific searches were narrowed to all 48 countries and 4 regions of SSA. We also used the proposed synonymous terms for our search.

2.2. Study selection and quality assessment

Potential full-text articles were evaluated for eligibility after reviewing titles and abstracts obtained from the searches. All the selected articles fulfilled the following inclusion criteria: cross-sectional study, study done in SSA with no language restriction, the country where the study was carried out as stated, was on the human host, exact total numbers and positive cases were reported. Studies without these indices were all excluded. All the studies that met the inclusion criteria were assessed for quality using a quality assessment checklist. Items were graded as yes, no, and undecided. The questions of the checklist were as follows: Was the purpose of the research clearly described? Was the sampling period mentioned? Was the sampling method defined? Was the sampling location indicated? Was the study design described? Was the host type stated? Was the sample size specified? Was there an appropriate statistical analysis? Was the method of diagnosis clearly stated? Was ethical approval obtained from the institutional ethics board?

These items were represented on a scale of 1–10. Each question represented a scale, and ten questions in all were used in assessing studies' quality. All studies were included regardless of study quality (Additional file 1).

2.3. Data extraction

Data were extracted using detailed characteristics of each study on pre-designed sub-headings in an excel data collection spreadsheet. From the qualifying studies, first author's surname, year of study, year of publication, population studied, country and area of study, risk factors such as housing floor materials, topographic sites of embedded sand fleas, water sources (well, river, tap), gender and types of domestic animals in and around the house, sample size, and the number of positive cases were all extracted from each study.

2.4. Data analysis

R software version 4.0.0, a tool for meta-analysis was adopted to pool the prevalence from each study. The overall pooled prevalence across studies was calculated using a random-effects model (DerSimonian and Laird method) that involved stabilizing the variances of the prevalence estimates first via logit transformation [20]. Study heterogeneity (Cochran's Q test) was evaluated by I^2 (level of inconsistency). The I^2 values of 25%, 50% and 75% were considered as a low, moderate and high degree of heterogeneity, respectively [21,22]. Potential sources of heterogeneity were further investigated using the sensitivity analysis, subgroup analysis, and meta-regression. Funnel plots and Egger's test statistics were used to investigate publication bias and small-study sample effects. Similarly, inferential statistics such as Chi-square analysis for sub-group evaluation of variables such as gender, floor materials, topographic sites, and respondent's water sources were done with GraphPad Prism (San Diego, U.S.A., version 5).

3. Results

3.1. Bibliography search and eligible studies

Figure 1 presents the flow diagram for selecting qualified studies and a list of excluded studies. Of the 104 published articles that were accessed, 94 were from databases, and 10 were from reference screening. After searching by titles, 62 duplicate studies were removed. A total of 15 studies (case report = 6, case series = 2, animal studies = 5, questionnaire study = 2) were removed from the 42 studies subjected to comprehensive abstract and full-text reviews, as they did not meet the inclusion criteria. A total of 27 published articles were included in the meta-analysis.

3.2. Characteristics of eligible studies

The list and characteristics of eligible studies are presented in Table 1. The included articles were all original

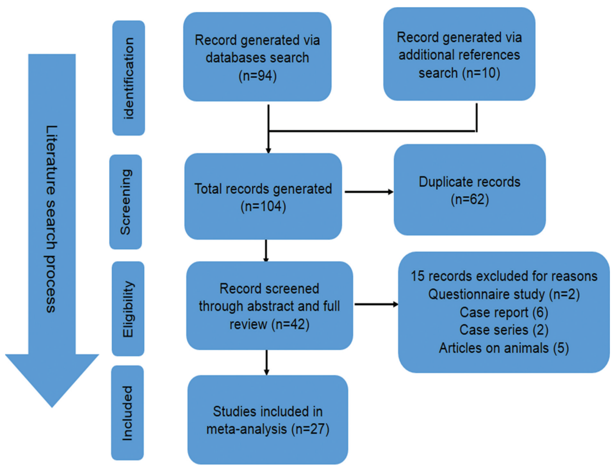

Figure 1. PRISMA flow diagram of included studies in the systematic review and meta-analysis on the epidemiology of tungiasis in sub-saharan Africa.

Table 1. List and characteristics of studies included in the meta-analysis.

First author	Country	County/district/State	Study location	Sample size	Cases	Year of Publication
Wafula	Uganda	Mayuge district	Bukatube sub-county	442	95	2016
Ugbomoiko	Nigeria	Lagos	Erekiti	557	252	2007
Ade-Serrano	Nigeria	Lagos	Oto- Ijanikin, Badagry	373	155	1981
Wiese	Kenya	Kilifi County	Kakuyuni and Malanga	1086	270	2017
Arene	Nigeria	River	Niger delta, Choba area	480	146	1984
Walker	Ethiopia	Gedeo Zone	Yirgacheffe	343	119	2017
Ejezie	Nigeria	Lagos	Epe. Ikorodu. Badagry, Ajegunle	247	600	1981
Collins	Cameroon	Ndu subdivision	Ndu	610	1151	2009
Njau	Cameroon	Murang'a	Murang'a South	218	385	2012
Girma	Ethiopia	Sidama zone	Wensho	2015	366	2018
Mazigo	Tanzania	Kasulu district	Nyansha and Nyakitonto	249	586	2012
Nyangacha	Kenya	Vihiga County	Hamuyundi, Viyalo and Evojo	94	437	2019
Mutebi	Uganda	Bugiri district	Makoma, Kibuye and Nagongera	254	1766	2015
Elson	Kenya	Kilifi County	Kakuyuni and Malanga	870	1829	2019
Njeumi	Cameroon	West Cameroon	Bafoussam, Tonga and Dschang	264	537	2002
Ugbomoiko	Nigeria	Lagos	Badagry, Ajido	133	545	2016
Ikpeze	Nigeria	Imo and Enugu	Owerri and Enugu	27	428	2008
Boure´e	Cameroon	Western Cameroon	Bangou	132	403	2012
Nte	Nigeria	Rivers	Rivers	49	218	1995
Nsanzimana	Rwanda	Southern Rwanda	Southern rural Rwanda	87	384	2019
Ngunjiri	Kenya	Murang′a	Kandara	153	347	2015
Mwangi	Kenya	Kiharu	Gaturi, Kimathi, Kahuhia, Mugoiri	97	508	2015
Waruguru	Kenya	Kericho	Kipkelion	229	428	2015
Aballa	Kenya	Otwenya, Maseno	Urudi Rata, Mbeka and Mariwa	31	78	2019
Otubanjo	Nigeria	Lagos	Badagry	293	1030	2016
Mwakanyamale	Uganda	Korogwe	Kwakombo	300	720	2015
Namuhani	Tanzania	Mayuge	Bukatube	74	296	2016

articles and cross-sectional in design. Twenty-five (92.6%) studies were published in the English language and two (7.4%) in the French language. The twenty-seven included studies were conducted in seven countries (Figure 2); (Nigeria = 8, Kenya = 8, Cameroon = 3, Uganda = 3, Tanzania = 2, Ethiopia = 2, and Rwanda = 1). Thus, East Africa contributed more data (59.3%) compared to West Africa, while no data from other regions of SSA (Central and Southern Africa) were reported. Twenty-one of the articles (77.8%) were community-based studies, while the remaining six articles (22.2%) were school-based studies. The sample size of the studies ranged from 78 in Kenya to 1,829 in the same country. In the final analysis, 5,663 cases (mean = 209.7) of tungiasis and 16,303 of participants (mean: 603.8) were used to estimate the pooled prevalence of infection with *Tunga penetrans* in SSA.

3.3. Pooled prevalence estimates and heterogeneity analysis

The pooled overall prevalence of tungiasis in SSA was 33.4% (95% CI: 28.3, 39.0), with substantial heterogeneity (Q = 1284.98, df = 26, $p < 0.0001$, $I^2 = 97.98\%$). The prevalence of individual studies varied from 6.3% in Nigeria to 58.7% in Ethiopia (Figure 3). The pooled prevalence of tungiasis was significantly ($P < 0.0001$) higher in East Africa (34.2%) compared to that of West Africa (32.3%). In Ethiopia, the pooled tungiasis prevalence of 46.5% (24.9–65.6) was much higher than in the other SSA countries where it ranged from 20.1% in Uganda to 44.9% in Cameroon. Prevalence estimates range between 33.8% (26.3–42.2) in studies published from 1980–1999 to 33.4% (27.6–39.7) for articles published from 2000–2020. Prevalence rates for study design ranged between 34.2% (95% CI: 27.9–41.0) in

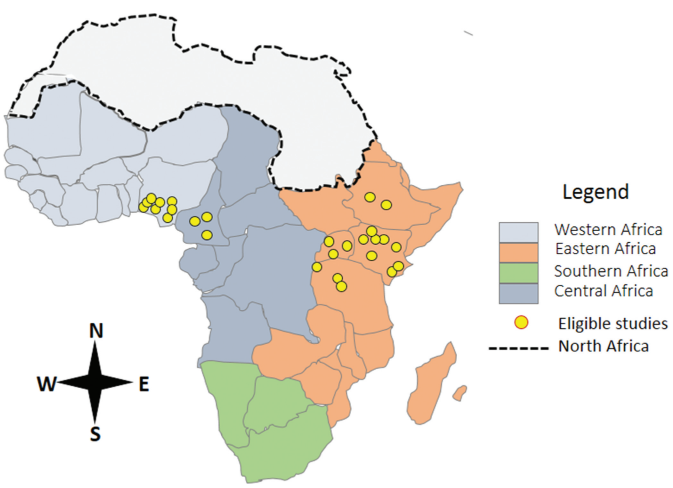

Figure 2. Map showing eligible studies across SSA. Source: Drawn by the author.

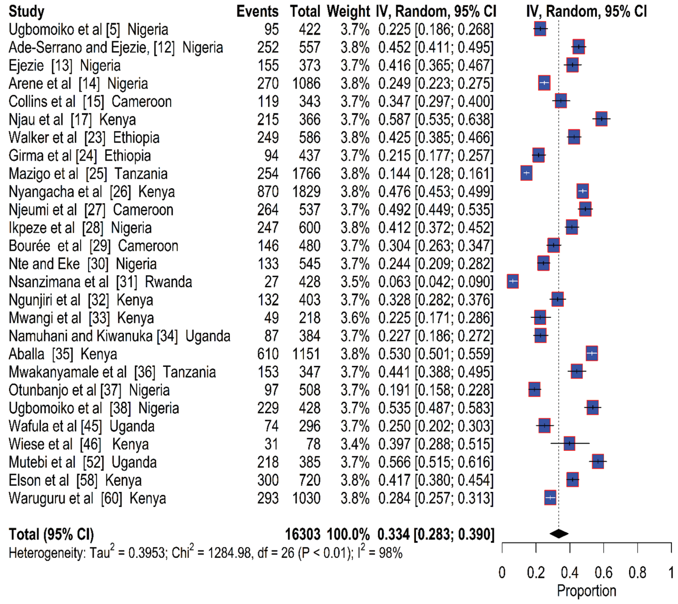

Figure 3. Forest plot of pooled prevalence of tungiasis in SSA [5,12–15,17,23–38,45,46,52,58,60]. NB: The area of each square is proportional to the study's weight in the meta-analysis, and each line represents the confidence interval around the estimate. The diamond represents the pooled estimate.Abbreviations: CI = confidence interval; df = degrees of freedom; IV = inverse variance.

community-based survey and 30.8% (95 %CI: 21.7–41.6) in a school-based survey. In terms of geo-locality, the pooled prevalence of tungiasis in rural residents was significantly higher, 35.0% (29.0–40.6) than in urban residents 6% (0.04–0.09) (Table 2).

3.4. Analysis of tungiasis risk factors in sub-saharan Africa

Meta-data analyses of the pooled prevalence of males (35.5 (28.6–42.9); Q = 283.69; P < 0.0001) was significantly higher (χ^2 = 26.3; OR = 1.3; P < 0.0001) when compared to females 27.4 (20.8–35.2) (Q = 331.47; P < 0.0001). Age groups of 4–15 years with a pooled prevalence of 42.9 % (28.9–58.3) was highest, followed by ≥60 years and 15–59 years at 24.7%, and 17.6% respectively. Participants whose house/school floor materials was made of earthen materials had a significantly higher pooled prevalence 53.2% (χ^2 = 252.7; OR = 3.3; Q = 499.28; P < 0.0001) when compared to those who had a cemented floor (20.0% (12.2–31.0); Q = 95.88; P < 0.0001). The overall pooled estimate reported the 'use of shoe prevalence' of tungiasis to be 61.0% (41.1–77.8) among non-regular users of footwear and 18.7% (9.2–34.1) for frequent

Table 2. Pooled prevalence and subgroup analysis of tungiasis in sub-saharan Africa.

Variable	TS	PC	PP (95%CI)	I^2 (%)	Cochran's Q	df α0.05	R^2 Chi², OR/F
Overall prevalence	16303	5663	33.4 (28.3-39.0)	97.98	1284.98	26 <0.0001	
Geographic region							
East Africa	9981	3355	34.2 (27.0-42.3)	98.30	880.29	15 <0.0001	0.00; χ^2=14.29; *OR*=0.9
West Africa	6322	2308	32.3(25.4-40.2)	97.50	392.71	10 <0.0001	
Country							
Nigeria	4231	1302	28.1 (21.2-36.3)	96.61	206.66	7 <0.0001	26.39; $F_{6, 20}$; P =0.039
Uganda	2484	423	20.1 (13.7-28.4)	93.43	30.43	2 <0.0001	
Cameroun	2091	1006	44.9 (34.0-56.2)	95.83	47.95	2 <0.0001	
Kenya	5098	1962	37.2 (27.3-48.3)	98.07	362.48	7 <0.0001	
Ethiopia	709	334	46.5 (24.9-65.6)	97.52	40.26	1 <0.0001	
Tanzania	1306	549	42.0 (39.4-44.7)	-	0.09	1 <0.7639	
Rwanda	384	87	22.7 (18.7-27.1)	0.00	-	- 1.0000	
Year published							
1980-1999	1671	597	33.8 (26.3-42.2)	91.44	35.03	3 <0.0001	0.00; χ^2=0.81; *OR*=1.0
2000-2020	14632	5066	33.4 (27.6-39.7)	98.23	1249.80	22 <0.0001	
Median Sample size							
<437	4471	1584	33.4 (25.4-42.5)	97.10	416.08	12 <0.0001	0.00; χ^2=1.3; *OR*=1.0
≥437	11832	4079	33.3 (25.3-42.0)	98.52	864.98	13 <0.0001	
Study design							
Community-based	12094	4110	34.2 (27.9-41.0)	98.13	1056.80	20 <0.0001	0.00; χ^2=11.69; *OR*=0.9
School-based	4209	1553	30.8 (21.7-41.6)	97.77	223.76	5 <0.0001	
Geolocality							
Rural	15875	5636	35.0 (29.0-40.6)	97.90	1167.44	25 <0.0001	0.00; χ^2= 156.68; *OR*=8.2
Urban	428	27	0.06 (0.04-0.09)	-	0.00	1 -	

Abbreviations: I^2 = level of inconsistency, df = degree of freedom, α0.05 = level of significance, OR = odd ratio, CI = confidence interval, TS = total sample, PC = positive cases, PP = pooled prevalence, χ^2 = chi-square.

footwear users. Participants who keep dogs had the highest pooled prevalence of 39.2 (21.9–59.8), followed by those who keep pigs, cats, goats, and chickens at 37.1%, 35.4 %, 27.0 %, and 25.0%, respectively. Individuals who use river water had the highest pooled prevalence of 50.8% (28.7–72.7), followed by those who use tap water and well water at 39.2% and 28.1% respectively. The prevalence of tungiasis increased significantly (χ^2 = 430.7; OR = 60.3) by the topographic site. The pooled prevalence of participants with lesions located on the feet ranged between 93.4% (12.1–99.9) and 20.6% (2.0–77.1) on the hand (Table 3).

3.5. *Sources of heterogeneity*

Since our meta-analysis showed large heterogeneity, to identify possible sources of heterogeneity, subgroup analysis was performed using geographic area, country, year of publication, median sample size, population surveyed and study setting. The chi-squared statistical tests for subgroup differences consistently yielded high I^2 statistic and heterogeneity chi-square test ($p < 0.0001$). In the meta-regressions, the percentage of the country in the total sample was the only statistically significant covariate, explaining 26.4% of the between-study heterogeneity in the prevalence of tungiasis.

3.6. *Sensitivity tests and assessment of bias*

To assess the robustness of our results, a leave-one-out sensitivity analysis was conducted by removing one study at a time and recalculating the overall effect estimate. The pooled estimate remained constant, suggesting that eliminating one particular study from the analysis did not change the pooled estimate significantly (Additional file 2). The presence of reporting bias was assessed by visually inspecting funnel plots for asymmetry. There was no evidence of asymmetry across all studies or by subgroups (Figure 4). Egger's test failed to provide evidence for small-study effects on the prevalence (p-value for bias = 0.107).

4. Discussion

Our study reported that the prevalence of tungiasis is heterogeneous in SSA, varying from one country to another, and region to region. The heterogeneity observed in this study may be attributed to differences in exposure rate, prevailing environmental conditions, behavioral and socioeconomic factors within these endemic regions [38].

Tungiasis is a paradigmatic example of a neglected tropical disease that is not given due attention and recognition by health authorities and health professionals, despite the widespread and substantial disease burden caused by the disease [39]. The current study revealed that one-third of the population in 7 SSA countries is affected by the disease. This is an indication that sufficient epidemiological data are not available on the disease and the social effects of morbidity associated with it are overlooked. Further epidemiological research is therefore desired by key stakeholders (academic community, health care providers, decision-

Table 3. Risk factors associated with tungiasis in sub-saharan Africa.

Variables	TS	PC	PP (95%CI)	I^2	Q Cochran df	α0.05	Chi^2, OR
Sex							
Male	3911	1360	35.5 (28.6–42.9)	95.07	283.69 14	<0.0001	^{2} = 26.3; *OR* = 1.3
Female	3819	1118	27.4 (20.8–35.2)	95.78	331.47 13	<0.0001	
Age							
4–15	4881	1516	42.9(28.9–58.3)	98.69	839.66 11	<0.0001	^{2} = 106.5; P = <.0001
15–59	1199	203	17.6(11.3–26.3)	89.96	89.96 7	<0.0001	
≥60	809	185	24.7(11.7–44.9)	95.79	118.84 5	<0.0001	
Floor materials in school/house							
Earthen	3512	1723	53.2 (38.6–67.4)	98.45	499.28 8	<0.0001	^{2} = 252.7; *OR* = 3.3
Concrete	1174	265	20.0 (12.2–31.0)	91.70	95.88 8	<0.0001	
Footwear							
No/occasionally	1169	652	61.0 (41.1–77.8)	97.38	114.31 3	<0.0001	^{2} = 34.3; *OR* = 1.9
Regularly	614	147	18.7 (9.2–34.1)	92.38	26.23 2	<0.0001	
Types of animals in and around the house							
Pigs	608	144	37.1 (5.0–87.0)	98.33	179.88 3	<0.0001	^{2} = 53.5; P = <.0001
Dogs	955	372	39.2 (21.9–59.8)	97.00	133.37 4	<0.0001	
Cats	486	139	35.4 (18.6–60.0)	91.45	46.76 4	<0.0001	
Goats	1104	334	27.0 (18.2–37.9)	90.89	32.92 3	<0.0001	
Chicken	731	190	25.0 (19.3–31.8)	72.19	7.19 2	0.0274	
Source of water							
Tap	431	176	39.2 (19.8–62.7)	95.06	60.67 3	<0.0001	^{2} = 71.3; P = <.0001
Well	403	89	28.1 (17.9–41.2)	74.08	15.43 4	0.0039	
River	859	403	50.8 (28.7–72.7)	97.38	114.59 2	<0.0001	
Topographic sites							
Feet	950	826	93.4 (12.1–99.9)	98.73	157.53 2	<0.0001	^{2} = 430.7; *OR* = 60.3
Hands	144	15	20.6 (2.0–77.1)	93.38	15.11 1	0.0001	

Abbreviations: I^2 = level of inconsistency, df = degree of freedom, α0.05 = level of significance, OR = odd ratio, CI = confidence interval, TS = total sample, PC = positive cases, PP = pooled prevalence, χ^2 = chi-square.

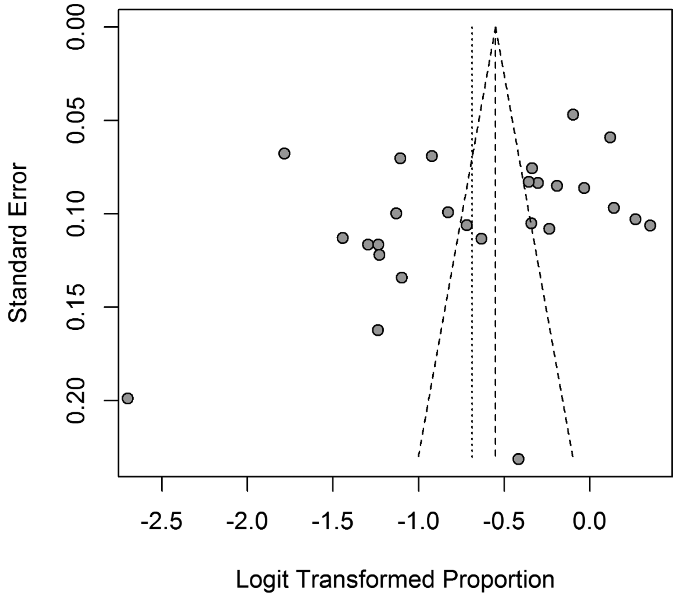

Figure 4. Funnel plot of tungiasis in sub-saharan Africa. The figure displays the observed effect size of each study against the standard error of each study.

makers, funding agencies as well as pharmaceutical companies) to identify high-transmission areas of tungiasis for additional prevention and new therapies.

In the last 20 years, the scientific community has been more active. There are more possible interventions of prevention and treatment and more awareness on the disease within, and across the population at risk. It may reflect the higher number of studies and a decrease of 0.4% in the prevalence of tungiasis found in this study. However, the non-inclusion of tungiasis among the NTDs could make it difficult for funding organizations to invest research funds in studying the disease in diverse dimensions because it's not on the priority list of health organizations (such as the WHO). The results of this study show that tungiasis is a problem of public health concern in rural areas and urban slums. The presence of inadequate or non-existent sanitation with sandy and pot-holed streets, houses without concrete floors, and the presence of stray domestic animals (especially dogs and pigs) may explain the higher prevalence of tungiasis infections in rural areas [39,40].

The prevalence of tungiasis by age followed a typical trend. The higher prevalence in children (age 5–14) and adults ≥60 years is expected. Children often work regularly on the farm from an early age and play around their community barefoot in dry, sandy courtyards where they can quickly be infected with sand fleas [41] while adults are more likely to identify and remove gravid female fleas. However, as age increases, older individuals may find removing embedded fleas a difficult task, as a result of poor eyesight and reduced flexibility associated with old age. These factors may explain the reasons for the age-prevalence trend in our review. The presence of tungiasis in children and the elderly can lead to a sense of shame and stigma. Tungiasis may also contribute significantly to children's school absenteeism, as well as hinder their typical outdoor activities. Thus, prevention and treatment measures should be tailored toward the at-risk group (children and the elderly) in the population.

This study, like those in Trinidad [42,43], observed a significant difference in the prevalence of tungiasis based on gender. However, this finding has not been consistent across all studies and tends to vary from one community to another. For example, in southern Brazil, it has been reported that infection with *Tunga penetrans* is more common in females than males, whereas other studies in Brazil and Nigeria have shown that more males are affected or that there is no significant gender difference [3,12,14,44]. The observed differences are likely to be related to exposure and environmental factors rather than differences in susceptibility [14].

Earlier works and our study suggested a connection between earthen floor materials and tungiasis [45,46]. The parasite's environment (The flea is known to live 2–5 cm below the sand level, a habitat without ample oxygen) explains its high prevalence in the earthen floor [47]. Walking or sleeping for many hours on such a floor without adequate barriers can increase the risk of contracting the disease. Human transmission can therefore be halted through appropriate environmental modification in cement flooring interventions, as opposed to earthen flooring typically used in huts and many rural villages in endemic regions.

Infection with *Tunga penetrans* occurs in all parts of the body [48]. However, both our review and others' observations have shown that infection occurs more in the feet [44,49]. *Tunga penetrans* is a weak jumper and does not reach far, a potential reason why the majority of lesions occur on the feet [50]. The presence of ectopic tungiasis is associated with kids often playing in pot-holed laden streets and backyards composed primarily of contaminated soil [49]. The prevalent habit of squatting among indigenous people may also suggest the ectopic lesions observed in the hands, thighs, perineum, and gluteal region [49]. Non-regular use or absence of footwear was also considered a risk factor. Consequently, the use of footwear should be considered as part of preventive measures. However, in areas where wearing flip-flops, or walking barefoot is a norm, wearing shoes can be uncomfortable for individuals, particularly those already infected with many sand flea lesions. Besides, children may find sturdy closed shoes as precious assets and tend to use them only for special occasions such as church attendance and on special celebrated events [51].

As previously noted by other investigators, and in congruence with this review's findings, the presence of dogs, pigs, cats, and goats in and around the house is an important predictor for becoming infected with tungiasis. These animals are known to host heavy loads of *Tunga penetrans*, live on compounds close to homes, either because of inadequate land to shelter them, out of fear of theft, or cultural practices [52–57]. However, the lesser risk of the involvement of chickens with tungiasis observed in this study may be due to the dense feathers on the body and the scaly legs that serve as barriers to sand fleas penetration [46,58,59]. The absence of adequate information did not allow us to examine the role of other domestic and sylvatic animals in the epidemiology of tungiasis. Because animals can play a role in the transmission for tungiasis, an eco-epidemiological approach ('One Health concept') should be considered for prevention and control.

Water sources showed a significant effect on the prevalence of infection with tungiasis from this study. There has been evidence of the indirect association between tungiasis and type of water supply, as shown by Waruguru et al. [60] and Ugbomoiko et al. [5]. Because tungiasis can be acquired peridomiciliary [61], individuals who trek for more than a kilometer before they can fetch improved water are likely to have tungiasis than those who have water in their homes. Moreover, families with poor access to a safe water supply service are likely to have low hygiene standards compared to those that are water secured [58].

5. Strength and limitations

Our review is comprehensive in scope and adds to the sparse information about the epidemiology of tungiasis in SSA. Given the useful evidence this analysis offers, it's not without limitations. The lack of data in most countries and the absence of adequate information to examine the role of certain risk factors associated with tungiasis in SSA are the limitations observed in this study.

6. Conclusion

The high burden of tungiasis, particularly in children and the elderly, may exacerbate complications including suppuration, ulceration, gangrene, tissue necrosis, deformation and the removal of nails, resulting in physical and psychological impairment and stigma. A holistic approach that combines the control of animal reservoirs, housing, and environmental control of modifiable factors, and health promotion are required. Intervention measures need to be designed by an interdisciplinary team together with the affected regions in SSA.

Authors' contributions

Conceptualisation: OOO and OOA; data acquisition and analysis: OOO and OOA, writing- original draft: OOO and OOA; writing review & editing: OOO and OOA, seeking final approval of the version to be published: OOO, and OOA. The manuscript has been read and accepted by the authors, who agree that the manuscript represents an honest piece of work and that the authorship criteria specified in this paper have been met.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Additional file 1. Study quality of the 27 included study.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall score (0–10)
Wafula	Y	N	Y	Y	Y	Y	Y	Y	N	Y	8
Ugbomoiko	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Ade-Serrano	Y	N	N	Y	Y	Y	Y	U	N	N	5
Wiese	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Arene	Y	Y	N	Y	Y	Y	Y	U	U	N	6
Walker	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	9
Ejezie	Y	N	N	Y	Y	Y	Y	N	N	N	5
Collins	Y	Y	N	Y	Y	Y	Y	U	Y	Y	8
Njau	Y	N	N	Y	Y	Y	Y	N	N	U	5
Girma	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Mazigo	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	9
Nyangacha	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Mutebi	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	9
Elson	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	9
Njeumi	Y	Y	Y	Y	Y	Y	Y	N	N	N	7
Ugbomoiko	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	9
Ikpeze	Y	Y	N	Y	Y	Y	Y	Y	N	N	7
Boure´e	Y	N	N	Y	Y	Y	Y	Y	N	N	6
Nte	Y	Y	N	U	Y	Y	Y	U	U	N	5
Nsanzimana	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9
Ngunjiri	Y	Y	N	Y	Y	Y	Y	Y	N	Y	8
Mwangi	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Waruguru	N	Y	N	Y	Y	Y	Y	Y	N	Y	7
Aballa	Y	N	N	Y	Y	Y	N	Y	Y	U	6
Otubanjo	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	9
Mwakanyamale	Y	Y	U	Y	Y	Y	Y	U	Y	Y	8
Namuhani	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9

Additional file 2.